Spring 2003

Physics 137A Section 1: Problem Set #1
Due: 5PM Friday Jan 31 in 2nd floor LeConte-Birge Cross-Over

Suggested Reading for this Week: This week's homework is on the historical origins of Quantum Mechanics. Griffiths does not cover this subject in his book.

- I have put on our web page an excellent review that was published in the SLAC beamline in Fall 2000. Please read *The Origins of the Quantum Theory* by Cathryn Carson from that review.
- Michael Fowler from University of Virginia has posted a good review of Black Body Radiation on his course web page. I have put a pointer to it on our web page.
- Chapter 1 of Bransden and Joachain is very complete and goes into more details than I have in class. I have taken some of the problems for this week from there.

Homework Problems:

1. (Bransden Problem 1.6) In Bransden and Joachain and in the Fowler article, the equation that describes the "spectral distribution," $\rho(\lambda, T)$, the energy per unit volume released in electromagnetic radiation in the wavelength interval between λ and $\lambda + d\lambda$ for a blackbody of temperature T is:

   $$\rho(\lambda, T) = \frac{8\pi hc}{\lambda^5}\frac{1}{exp(hc/\lambda kT) - 1}$$

   where h is Planck's constant, c is the speed of light and k is the Boltzman constant. Prove thtat the total energy density $\rho_{TOT} = aT^4$ where $a = 8\pi^5 k^4/15h^3c^3$. Hint: $\int_0^\infty \frac{x^3}{e^x - 1} dx = \frac{\pi^4}{15}$

2. (Bransden Problem 1.13) In a photoelectric experiment in which monochromatic light of wavelength λ falls on a potassium surface, it is seen that it requires a potential of 1.91 V to stop an electron that is produced if $\lambda = 300$ nm is used. A potential of 0.88 V is required if $\lambda = 400$ nm.

(a) Find a value for Planck's constant. You may use the fact that the charge of an electron is 1.6×10^{-19} C.

(b) Find the work function for potassium (the work function is the energy required to pull an electron from the surface of the metal)

(c) What is the threshold frequency for potassium (ie the lowest frequency for which it is possible to pull an electron from the metal)

3. Show that a free electron cannob absorb a photon and conserve both energy and momentum in the process (hence the photoelectric effect requires a bound electron).

4. (Bransden Problem 1.15) An x-ray photon of wavelength $\lambda_0 = 1$ Angstrom is incident on a free electron which is initially at rest. The photon is scattered at an angle $\theta = 30^\circ$ from the incident direction.

   (a) Calculate the Compton shift $\Delta\lambda$

   (b) What is the angle ϕ (measured from the incident photon direction) at which the electron recoils?

   (c) Whiat is the kinetic energy of the recoiling electron?

   (d) What fraction of its original energy does the photon loose?

5. (Bransden Problem 1.25) Calculate the de Broglie wavelength of:

   (a) A mass of 1 g moving with a velocity of 1 m/s

   (b) A free electron having a kinetic energy of 200 eV

   (c) A free electron having a kinetic energy of 50 GeV (1 GeV = 10^9 eV)

   (d) A free proton having a kinetic energy of 200 eV

   Hint: for (c) you must use the relativistic expression for momentum